

# Suppression of two-spotted spider mite (*Tetranychus urticae*), mealy bug (*Pseudococcus* sp) and aphid (*Myzus persicae*) populations and damage by vermicomposts

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## Abstract

A vermicompost, produced commercially from food wastes, was tested for its capacity to suppress populations and damage to plants, by two-spotted spider mites (*Tetranychus urticae*), mealy bugs (*Pseudococcus* sp.) and aphids (*Myzus persicae*), in the greenhouse. A range of mixtures of food waste vermicompost and a soil-less bedding plant growth medium Metro-Mix 360 (MM360) was tested in cages (40 cm × 40 cm × 40 cm) (0.2 mm mesh aperture) into which known numbers of greenhouse-bred pests were released. The crops tested were cucumbers and tomatoes for mealy bugs, bush beans and eggplants for spider mites, and cabbages for aphids. In all experiments, four 10 cm diameter pots, each containing one seedling, grown in the same MM360/vermicompost mixture were exposed to either 50 mealy bugs, 100 spider mites, or 100 aphids in cages, with each cage treatment replicated 4 times per treatment. The five growth mixtures tested were: (i) 100% MM360; (ii) 90% MM360 with 10% vermicompost; (iii) 80% MM360 with 20% vermicompost; (iv) 60% MM360 with 40% vermicompost; and (v) 20% MM360 with 80% vermicompost. Almost all of the mixtures containing vermicomposts suppressed the arthropod pest populations, and decreased pest damage significantly, compared with the MM360 controls. Not only did the vermicomposts make the plants less attractive to the pests, but they also had considerable effects on pest reproduction over time. The effects of the vermicompost substitutions tended to be least on spider mites, intermediate on mealy bugs, and greatest on aphids; however this may relate to the motility of the pests, as well as to the suppression potential of vermicomposts. Possible mechanisms for the suppression discussed include: the form of nitrogen available in the leaf tissues, the effects of vermicomposts on micronutrient availability, and the possible production of phenols, by the plants after applications of vermicomposts, making the tissues unpalatable. © 2006 Elsevier Ltd. All rights reserved.

**Keywords:** Spider mites; Mealy bugs; Aphids; Cucumbers; Tomatoes; Bush beans; Eggplants; Vermicomposts; Pest suppression

## 1. Introduction

Vermicomposts, which are produced from organic wastes by interactions between earthworms and microorganisms in a mesophilic process, are finely divided, fully stabilized organic materials with large microbial populations and activity. Low vermicompost application rates in the field, or substitutions into plant growth media in the greenhouse, have been shown to increase crop growth dramatically and significantly independent of nutrient

supply (Edwards and Arancon, 2004). Vermicomposts have also been shown to suppress populations of plant parasitic nematodes (Arancon et al., 2002) and plant pathogens in our laboratory (Chaoui et al., 2002).

There are reports in the literature which indicate that various forms of organic matter applied to soils, may be able to decrease populations of arthropod pests and resultant crop damage (Patriquin et al., 1995). In preliminary experiments in our laboratory, vermicomposts have been shown to suppress populations and damage by arthropod pests, such as aphids and cabbage white caterpillars (Arancon and Edwards, 2004; Arancon et al., 2005). Other workers have reported that vermicomposts

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suppressed numbers of jassids, aphids and spider mites (Rao et al., 2001; Rao, 2002). The greenhouse experiments reported in this paper, assess the effects of food waste-based vermicomposts on populations and damage by mealy bugs (*Pseudococcus* sp.) to cucumbers and tomatoes, the damage by two-spotted spider mites (*Teranychus urticae*) to bush bean seedlings and eggplants and the populations and damage by aphids on cabbages. The influences of adding fertilizers, or providing no fertilization, on the extent of pest infestations and plant damage were also studied, with the aim of identifying the effects of fertilization on arthropod pest suppression by vermicomposts.

## 2. Materials and methods

### 2.1. Design of greenhouse experiments

The greenhouse experiments were in the Biological Sciences Greenhouse at the Ohio State University, Columbus, Ohio. Cucumbers, tomatoes, bush beans, eggplants, or cabbages were sown and grown in a soil-less, commercial greenhouse container, bedding plant medium Metro-Mix 360 (MM360), substituted with different rates of food waste-based vermicompost. MM360 is a preparation of vermiculite, Canadian sphagnum peat moss, bark ash, sand, and has a starter nutrient fertilizer in its formulation (Scotts, Marysville, OH). The food waste vermicompost used, which was produced by Oregon Soil Corporation, Portland Oregon, contained 1.3% N, 2.7% P, and 9.2% K. Each of the experiment tested different rates of substitutions of food waste vermicompost into MM360 (which were all in the same range) on the three arthropod pests.

Four seeds of the appropriate crop were sown into each 10 cm diameter pot, containing MM360 or one of a range of mixtures of food waste vermicompost with MM360. The seedlings were thinned to one seedling per pot seven days after sowing. The treatments included: (i) crops grown in MM360 soil-less plant grown medium and exposed to pests (control); (ii) crops grown in a 10% food waste vermicompost and 90% MM360 mixture and exposed to pests; (iii) crops grown in a 20% food waste vermicompost and 80% MM360 mixture and exposed to pests; (iv) crops grown in a 40% food waste vermicompost and 60% MM360 mixture and exposed to pests; (v) crops grown in a 80% vermicompost and 20% MM360 mixture and exposed to pests. A range of these mixtures were used in each individual experiment as detailed below under the individual pest sections.

Each experimental treatment, involved growing seedlings of the appropriate plant species in four pots as subsamples, all confined in a single mesh cage (40 cm × 40 cm × 40 cm with a 0.2 mm aperture mesh). Each treatment was replicated four times. The seedlings were raised in an insect-free greenhouse environment for four weeks. For spider mites, mealy bugs and aphids plants in cages were placed on capillary mats for ease and uniformity of

watering, either with Peters Nutrient Solution, providing all the required nutrients, or watering with only water, according to the experiment protocol designated. In each experiment, duplicate sets of four plants each in cage were grown in identical vermicomposts and MM360 mixtures, with no arthropod infestations, so they could be used as a basis for comparisons with the plants infested artificially with pests.

Each experiment was laid out in the greenhouse in a completely randomized design (CRD). Data were analyzed using the same designs in SAS statistical software. Differences between means were separated using least significant difference (LSD) at  $P < 0.05$  and  $< 0.01$ , as indicated in the captions to the Figures.

### 2.2. Mealy bug experiments

In a preliminary experiment, the suppression of mealy bugs on cucumber by vermicomposts was assessed in pots each with one cucumber seedling, grown in a range of vermicompost and MM360 mixtures, which were placed in standard cages and infested with mealy bugs. The treatments were: (i) 100% MM360 (control), (ii) 80% MM360 with 20% food waste vermicompost; and (iii) 60% MM360 with 40% food waste vermicompost, all replicated four times. In the 5th week of seedling growth, the cages were laid out at random on greenhouse benches on capillary mats. Fifty mealy bugs (*Pseudococcus* sp.) were released into each infested cage, containing four 10 cm pots each with a single cucumber seedling. No mealy bugs were released into a second set of control cages consisting of cucumber seedlings, sown and grown with identical treatments and number of replications, for comparisons with the infested plants. After 25 days, the numbers of mealy bugs on each plant were counted, leaf areas were measured (using a Licor leaf area meter), plant heights recorded, roots removed and the above-ground dry weight of each plant recorded.

A second experiment, studied the development of suppression of mealy bug infestations, reproduction and damage on tomatoes by food waste vermicomposts, in time. The growth mixtures tested in this experiment were: (i) 100% MM360 (control), (ii) 90% MM360 with 10% food waste vermicompost; (iii) 60% MM360 with 40% vermicompost; and (iv) 80% MM360 with 20% vermicompost, all treatments replicated four times. At the beginning of the experiment, 50 mealy bugs were released into each cage, containing four pots, each with a single tomato seedling, growing in the same growth mixture. No mealy bugs were released into a second identical set of cages with tomato seedlings growing in the same range of mixtures and number of replications for comparison with infested plants. The numbers of mealy bugs on the foliage of all infested tomato plants were counted 11, 13, 16, 18, 20, 23, and 25 days after the release of mealy bugs into the cages. After 25 days, all plants were harvested, plant foliar losses were calculated using a Licor leaf area meter, plant heights

measured, and the above-ground dry weight of each plant was recorded.

### 2.3. Spider mite experiments

The first spider mite experiment aimed to assess the effects the suppression of spider mite damage by vermicompost. Four bush bean seeds were sown into each 10 cm diameter pot and thinned to one seedling per pot, containing the following mixtures as experimental treatments: (i) 100% MM360 (control); (ii) 80%MM360 and 20% vermicompost; or (iii) 60% MM360 and 40% vermicompost. All treatments were replicated four times as in the mealy bug experiments. The spider mites released into each cage were reared under controlled conditions (20 °C) in our greenhouse insectary. One hundred two-spotted spider mites were released into each of the control and vermicompost-treated cages. A second set of cages, which had the same range of MM360 or vermicompost/MM360 mixture treatments, had no mites introduced, so they could serve for the assessment of bush bean growth without pest attacks. All cages were placed on capillary mats for uniformity of watering arranged in a CRD.

The plants were watered three times weekly with a 200 ppm Peter's Nutrient Solution, providing all the nutrients that the plants needed. After 15 days, all plants were harvested and leaf damage assessed. Leaf damage on bush beans due to spider mites is characterized by yellow spots or a general chlorosis of the leaves. The damage ratings were based on the extent of distribution of these spots on the surface of the leaves: 0 representing no chlorosis and 5 showing that the leaf surface was completely covered with yellow spots caused by spider mites or completely chlorosed. Plant heights were measured and plant leaf areas were determined with a Licor leaf area meter, roots were removed and the above-ground dry weight of each plant recorded.

A second experiment studied the suppression of two-spotted spider mites infestations, by food waste vermicomposts, on 2-week-old eggplant seedlings in time. Four eggplant seeds were sown into each pot and later thinned to one seedling. The treatments were: (i) 100% MM360 (control); 90% MM360 with 10% food waste vermicompost; (ii) 60% MM360 with 40% vermicompost; and (iii) 80% MM360 with 20% vermicompost, with each mixture replicated four times. At the beginning of the experiment, 100 two-spotted spider mites were released into each cage with four pots each containing a single eggplant growing in the same growth mixture. No two-spotted mites were released into an identical second set of control cages with eggplant seedlings growing in identical range of vermicompost/MM360 mixtures for comparison with growth of infested plants. The infested and non-infested sets of cages were repeated in this experiment both sets containing the same vermicompost/MM360 treatments. One set received Peters nutrient solution three times a week through a capillary mat and the other set received only

water, to assess the effects of nutrients on rates of infestation. The damage ratings of spider mites on the foliage of all infested eggplants were assessed, using the same rating scale as the first experiment 3, 6, 8, 10, 13, 15 and 17 days after the release of two-spotted spider mites into the cages. After 4 weeks, all plants were harvested, plant foliar losses were calculated using a Licor leaf area meter, plant heights and the above-ground dry weights of each plant recorded.

### 2.4. Aphid experiments

The suppression of aphid populations, reproduction and damage to cabbages by vermicomposts was investigated in another set of experiments. The treatments were: (i) 100% MM360 (control); (ii) 80% MM360 with 20% food waste vermicompost; and (iii) 60% MM360 with 40% food waste vermicompost. Each growth mixture treatment consisted of four 10 cm diameter pots with a single cabbage seedling per pot, caged under a 40 cm × 40 cm × 40 cm (0.5 mm aperture) nylon mesh cage, as in the two-spotted spider mites experiment. All treatments were replicated four times. One hundred aphids were released into each cage. A similar set of replicated cages with cabbages grown in identical vermicompost/MM360 growth treatments were not infested with aphids, for comparison of cabbage growth with that of infested treatments. The infested and non-infested sets of cages were duplicated in this experiment containing identical MM360 or vermicompost/MM360 treatments, one set receiving Peters nutrient solution three times a week through a capillary mat and the other set receiving only water. All cages were arranged in the greenhouse on capillary mats for uniformity of watering in a CRD.

The numbers of aphids on the foliage were counted 3, 6, 8, 10, 13, 15, and 17 days after infestation. After 17 days, the amounts of leaf damage, heights of plants and plant leaf areas were measured using a Licor leaf area meter, roots were removed and the above-ground dry weight of each plant was recorded.

## 3. Results

In the first experiment, the numbers of mealy bugs were suppressed significantly ( $P \leq 0.05$ ) in response to 40% substitution of food waste vermicomposts into MM360 (Fig. 1). In the second experiment, the numbers of mealy bugs infesting the caged tomato plants, in response to 0%, 10%, 40%, and 80% substitutions of food waste vermicompost into MM360, are summarized in Fig. 2. The mealy bugs in the MM360 only treatment (control) reproduced quite rapidly, but mealy bug reproduction was almost completely suppressed by 40% or 80% vermicompost substitutions into 60% or 20% MM360, respectively. The leaf area changes on plants grown in MM360/vermicompost mixtures were significantly different ( $P \leq 0.05$ ) from those of plants growing in MM360

(Fig. 3). The decreases in mealy bug establishment and reproduction, in the vermicompost/MM360 mixtures compared with the MM360 control, were associated with increased leaf areas and shoot dry weights (Fig. 3).

In the experiments assessing the effects of infesting bush beans with two-spotted spider mites, damage by these arthropods was suppressed significantly ( $P \leq 0.05$ ) by both 20% and 40% substitutions of vermicompost into 80% and 60% MM360. Plants in the MM360 control lost

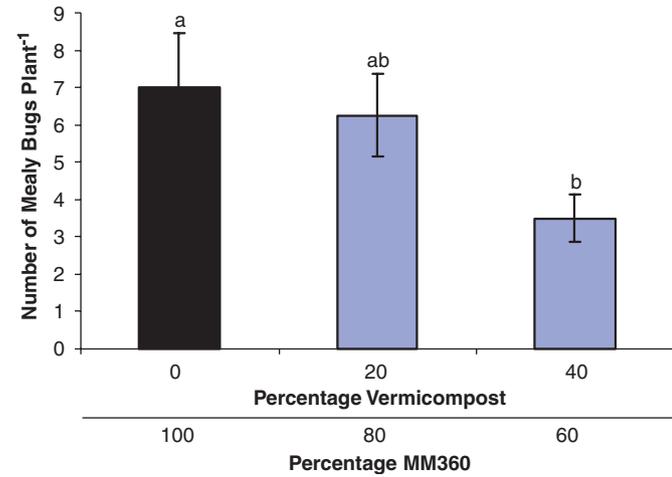


Fig. 1. Numbers of mealy bugs (Means ± S.E.) on cucumber seedlings planted in soilless medium Metro-Mix 360 (MM360) substituted with vermicomposts and supplied with all necessary nutrients in the greenhouse. Means followed by same letter(s) are not significantly different at  $P \leq 0.05$ .

significantly more leaf area, than those grown in pots with MM360 substituted with 20% and 40% vermicompost. All plants were supplied with all required nutrients (Fig. 4).

In the second experiment, as evidenced by plant damage, spider mites on eggplant seedlings established and reproduced rapidly in the MM360 control, but established much less in the 20% vermicompost with 80% MM360 and least of all in the 40% vermicompost with 60% MM360 mixture, when all required nutrients were supplied (Fig. 5(a)). The degree of development of spider mite damage was similar in all of the treatments, whether with or without nutrients, although there appeared to be more reproduction, in those treatments where no nutrients were supplied (Fig. 5(b)). The leaf areas, heights, and shoot dry weights of the eggplants all increased significantly ( $P \leq 0.05$ ) in response to the decreased damage by spider mites to the eggplants, in substitutions of 20% or 40% of food waste vermicomposts with 80% or 60% of MM360, when all the needed nutrients were supplied (Fig. 6). When no nutrients were supplied, the degree of depression of spider mite damage was less, and there were no significant effects ( $P \leq 0.05$ ) on eggplant leaf areas, shoot dry weights, or heights (Fig. 7).

In the experiments on the effects of vermicomposts on suppression of aphid populations and damage to cabbages, both of the 20% and 40% substitution rates of food waste vermicompost with 80% and 60% MM360, respectively, had dramatic effects compared with the MM360 control, on both the establishment and reproduction in time of the aphids, whether nutrients were supplied or not (Fig. 8). All these effects were significant ( $P \leq 0.05$ ), for all pest counts

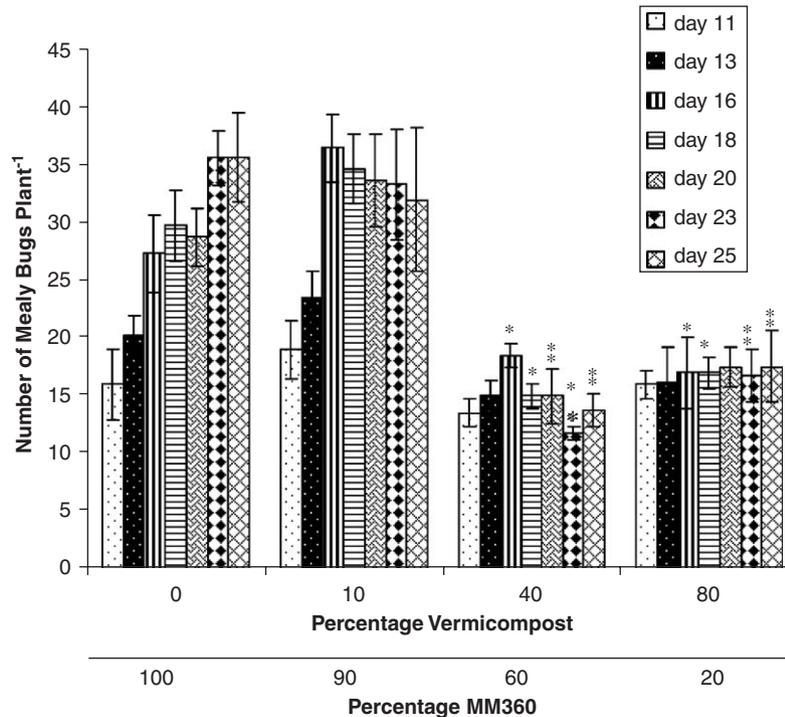


Fig. 2. Development of mealy bug populations on tomato plant (Means ± S.E.) grown in mixtures of food waste vermicompost and Metro-Mix 360 (MM360), and supplied with all needed nutrients. Populations were recorded on seven dates over 25 days after mealy bug infestations. Means designated by \* and \*\* are significantly different at  $P \leq 0.05$  and  $\leq 0.01$ , respectively.

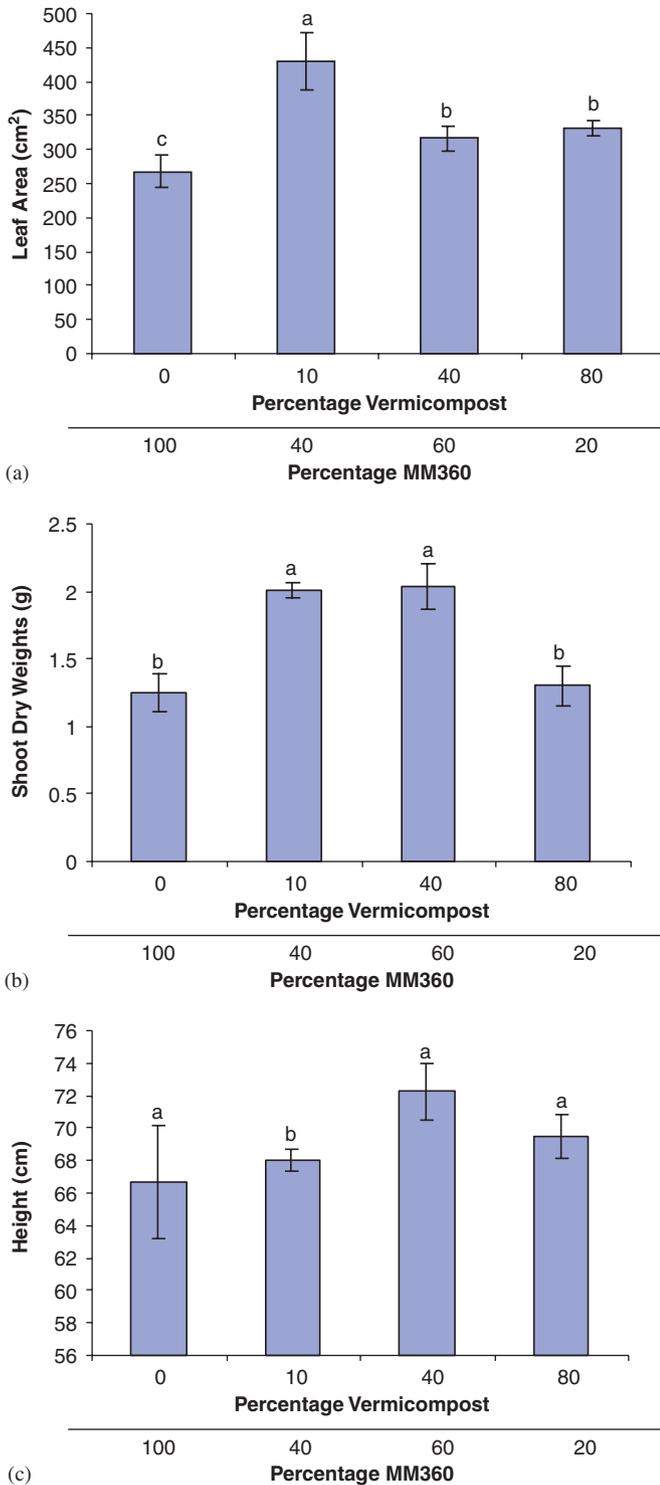


Fig. 3. Effects of two-spotted spider mites on (a) leaf areas (b) shoot dry weights (c) plant heights after 17 days of mealy bug attacks (Means  $\pm$  S.E.) on tomatoes grown in the greenhouse, in mixtures of food waste vermicompost and Metro-Mix 360 (MM360), and supplied with all required nutrients. Means followed by same letter(s) are not significantly different at  $P \leq 0.05$ .

between 8 and 17 days after the aphid infestations. When no nutrients were added, the differences in aphid populations and reproduction between MM360 control treatment and MM360/vermicompost mixtures became even more

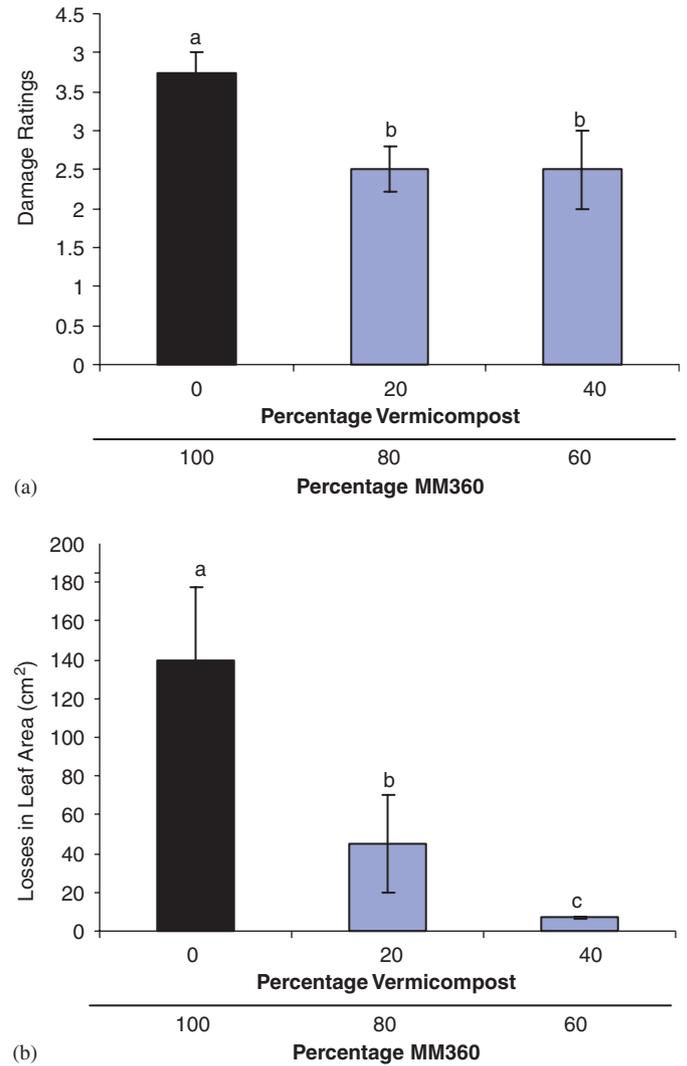


Fig. 4. Effects of two-spotted spider mites on (a) damage ratings (0 = no damage to 5 = severe damage) (Mean  $\pm$  S.E.) (b) changes in leaf area due to spider mite attacks on bush bean seedlings grown in mixtures of vermicompost and Metro-Mix 360 (MM360), after 15 days with all needed nutrients supplied. Means followed by same letter(s) are not significantly different at  $P \leq 0.05$ .

significant ( $P \leq 0.01$ ) after 15 and 17 days (Fig. 8(b)). These dramatic changes in populations of aphids, in response to vermicompost substitutions into MM360, resulted in significant increases in the leaf areas and dry weights of cabbages, whether nutrients were supplied (Fig. 9), or not (Fig. 10).

#### 4. Discussion

There is a very sparse literature recording the suppression of pest arthropods that attack crop plants by sucking plant foliage by vermicomposts, and most is published in rather obscure journals. For instance, there have been reports of vermicomposts suppressing attacks of sucking insects, such as jassids, aphids, and spider mites very significantly on groundnuts in India (Rao, 2002, 2003).

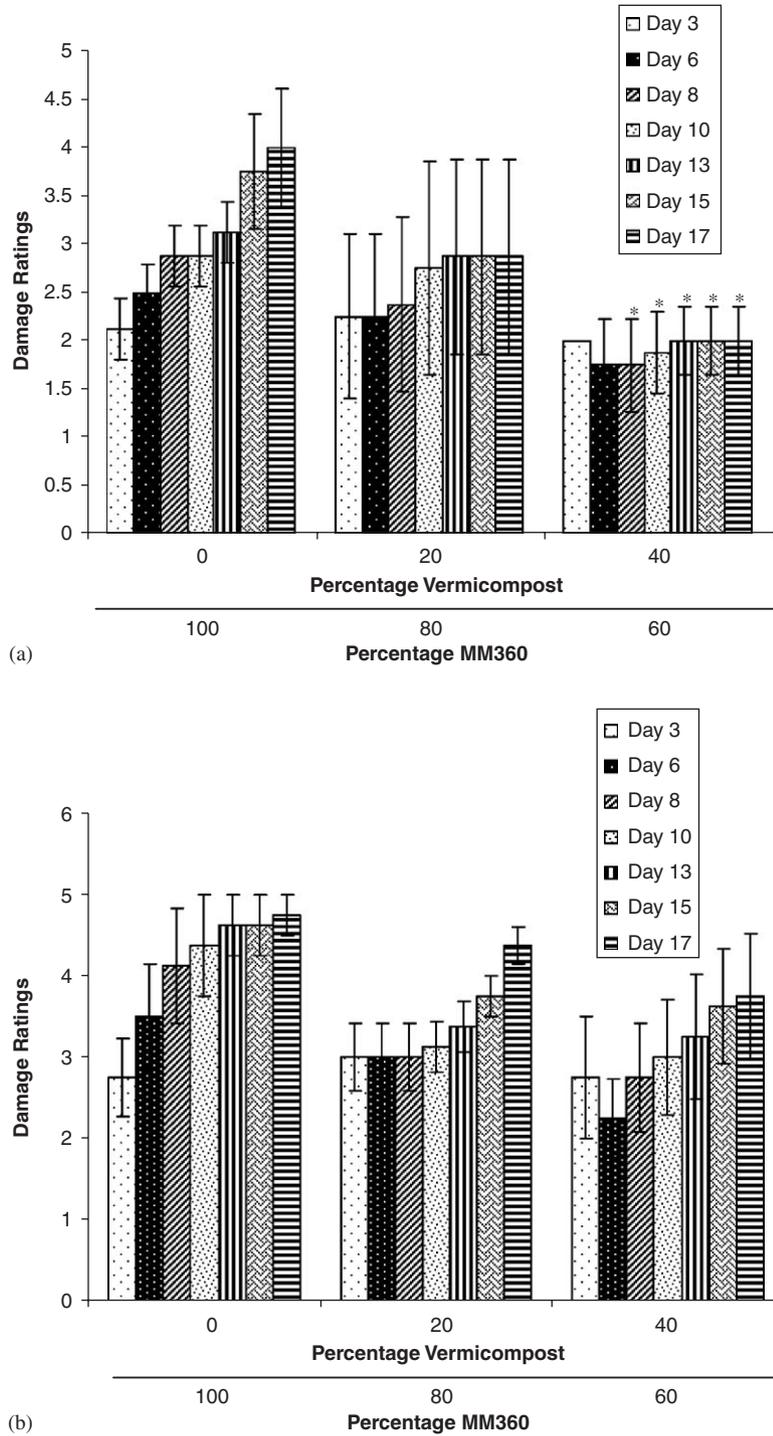


Fig. 5. Damage ratings by spider mites on eggplants (Means  $\pm$  S.E.) grown in Metro-Mix 360 (MM360) and food waste vermicompost mixtures (a) with all nutrients required (b) without nutrients, on seven dates, over 17 days following mite infestations (0 = no damage; 5 = severe damage). Means designated by \* and \*\* are significantly different at  $P \leq 0.05$  and  $\leq 0.01$ , respectively.

Biradar et al. (1998) reported a clear correlation between amounts of vermicompost in a growing medium and decreased incidence of psyllids (*Heteropsylla cubana*) on a tropical leguminous tree (*Leucaena leucocephala*). Arancon and Edwards (2004) and Arancon et al. (2005) reported suppression of aphids (*Myzus persicae*) on cabbages by vermicomposts.

The results from the greenhouse experiments that we report here demonstrated clearly that populations and damage by mealy bugs, spider mites, and aphids to artificially infested plants, differed greatly between plants grown in a soilless medium with only inorganic fertilizers, compared with those grown with vermicompost applications, when required nutrient inputs (NPK) were supplied

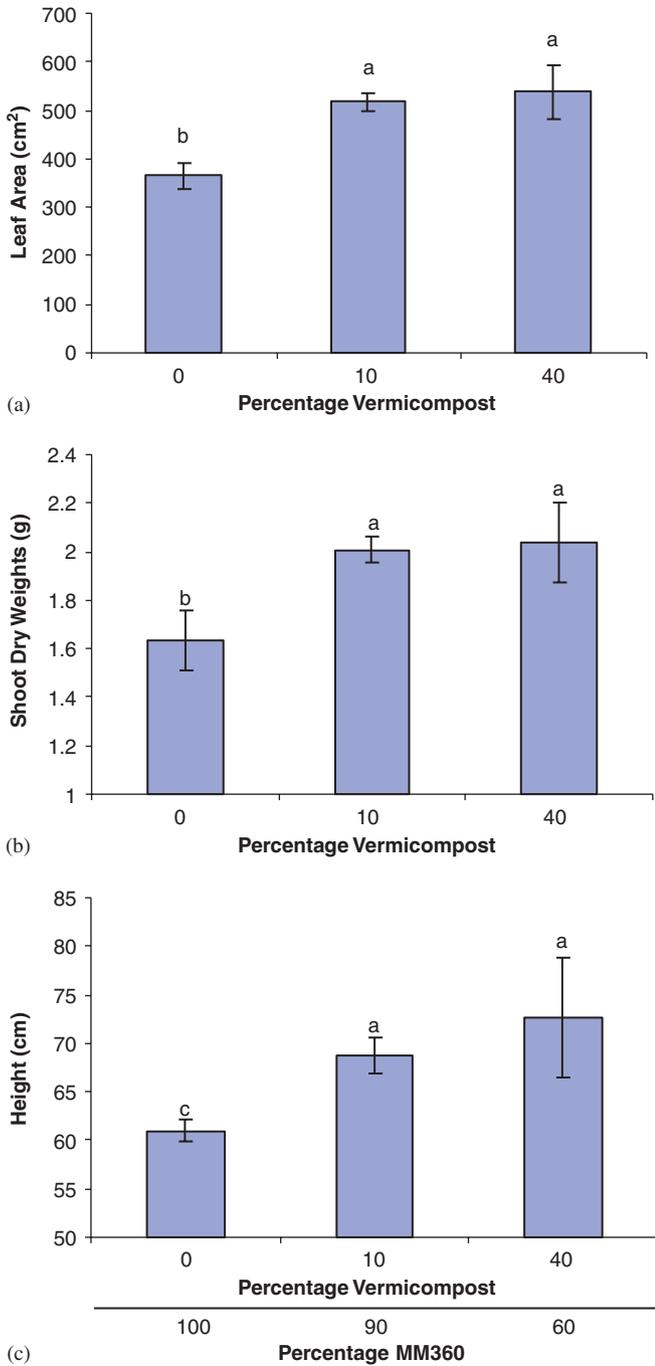


Fig. 6. Effects of two-spotted spider mites on (a) leaf areas (b) shoot dry weight (c) heights of eggplants (Means±S.E.) grown in Metro-Mix 360 (MM360) and food waste vermicompost mixtures, with all needed nutrients, 17 days after spider mite infestations. Means followed by same letter(s) are not significantly different at  $P \leq 0.05$ .

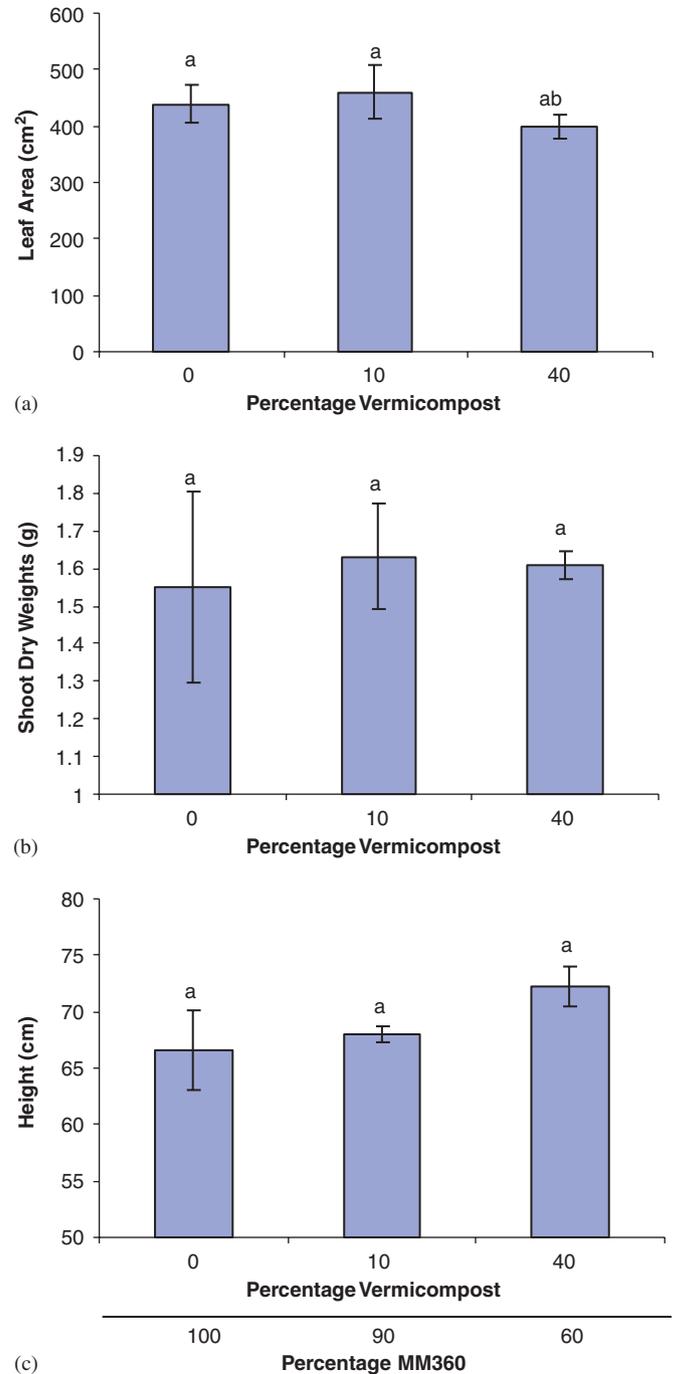


Fig. 7. Effects of spider mites on eggplants (a) leaf areas (b) shoot dry weights (c) height of eggplants (Means±SE) grown in Metro-Mix 360 (MM360) and food waste vermicompost mixtures with no additional nutrients, 17 days after spider mite infestations. Means followed by same letter(s) are not significantly different at  $P \leq 0.05$ .

into all treatments. The few reports in the literature, on the influences of vermicomposts on pest incidence and damage also suggest that pests are suppressed by vermicomposts and research into the effects of organic and inorganic fertility sources on pest arthropod populations has shown consistently larger populations of arthropods on plants grown with inorganic fertilizers, than on plants grown with organic amendments (Culliney and Pimentel,

1986; Eigenbrode and Pimentel, 1988; Yardim and Edwards, 2003). For instance, Patriquin et al. (1995) reported more aphids, *Aphis fabae*, on plants grown with urea applications than on those in organically managed soils. Morales et al. (2001) reported larger populations of aphids (*Rhopalosiphum maidis*) on corn grown with an inorganic fertilizer than on corn grown with organic amendments.

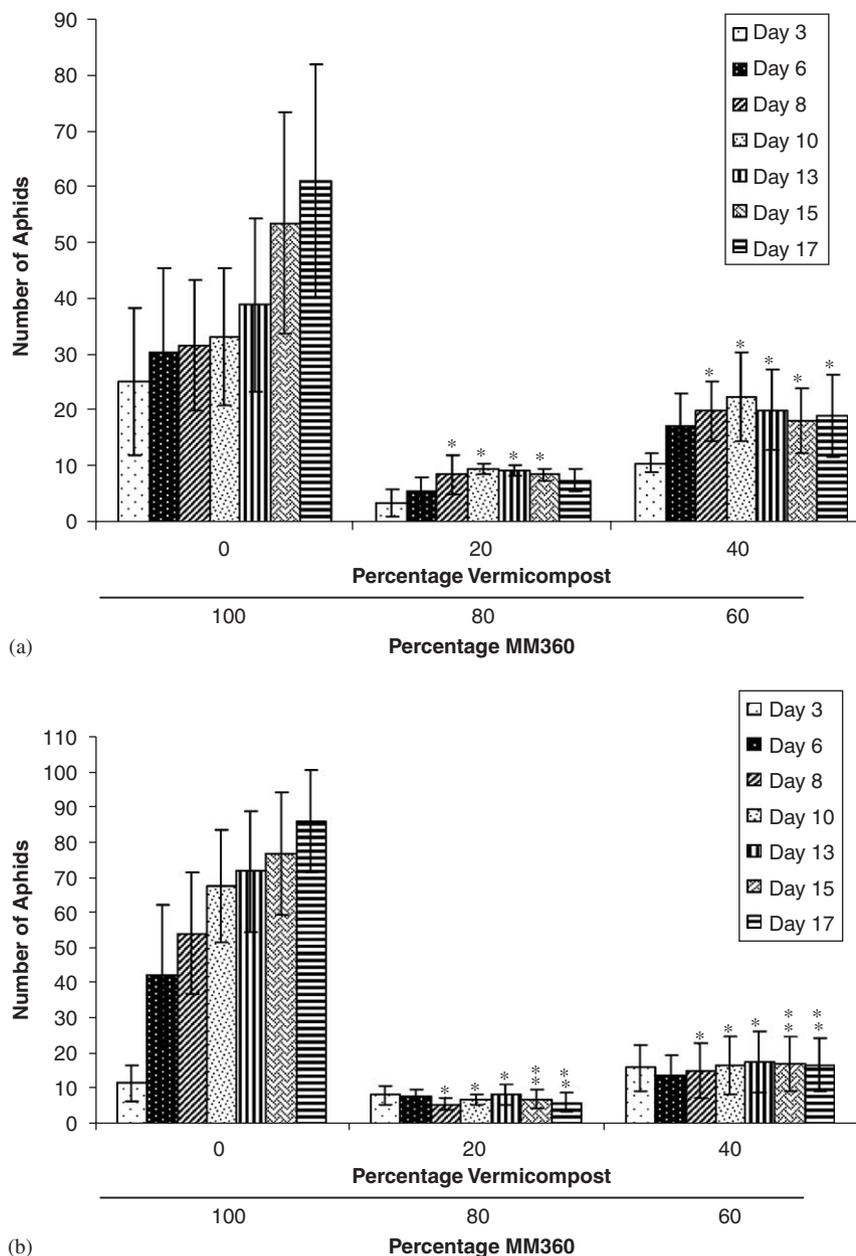
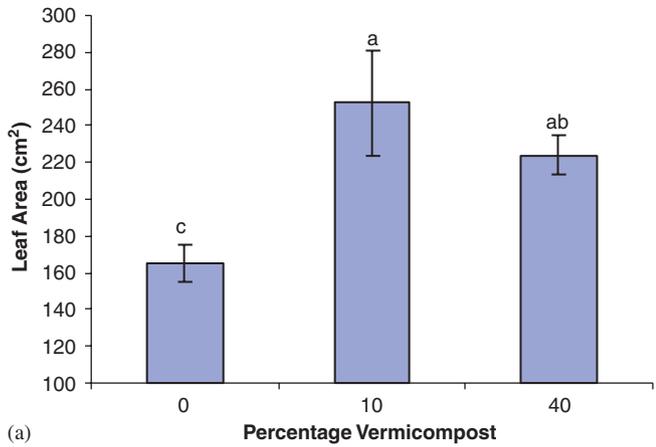


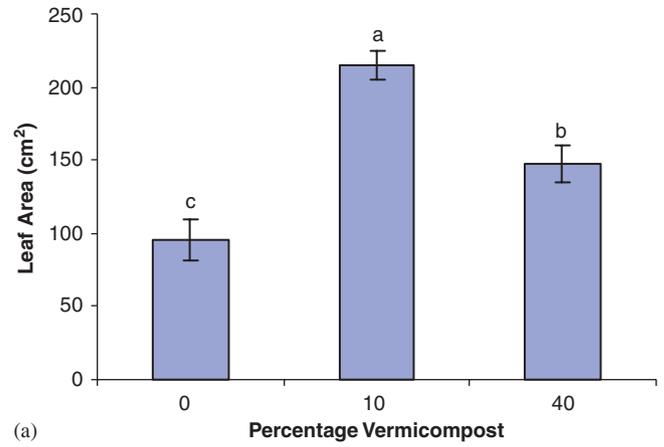
Fig. 8. Development of aphid populations (Means  $\pm$  SE) on cabbages, grown in a soilless medium, Metro-Mix 360 (MM360), substituted with food waste vermicomposts and: (a) supplied with all necessary nutrients (b) without any additional nutrients. Measurements made over on seven dates over 17 days after infestations. Means designated by \* and \*\* are significantly different at  $P \leq 0.05$  and  $\leq 0.01$ , respectively.

It has been reported by several authors (e.g. Phelan, 2004) that plants grown with organic fertilizers are usually attacked by fewer arthropod pests, and can resist pest attacks much better than plants that receive inorganic fertilizers; however possible ecological mechanisms driving this phenomenon are poorly understood. Some workers have suggested that inorganic N fertilization may decrease plant resistance to insects, by improving the nutritional quality and palatability of the host plants, and inhibiting the build up of secondary metabolite concentrations (Fragoyiannis et al., 2001; Herms, 2002). It has also been suggested that N may stimulate the fecundity of insects, attract more individuals for oviposition on host plants

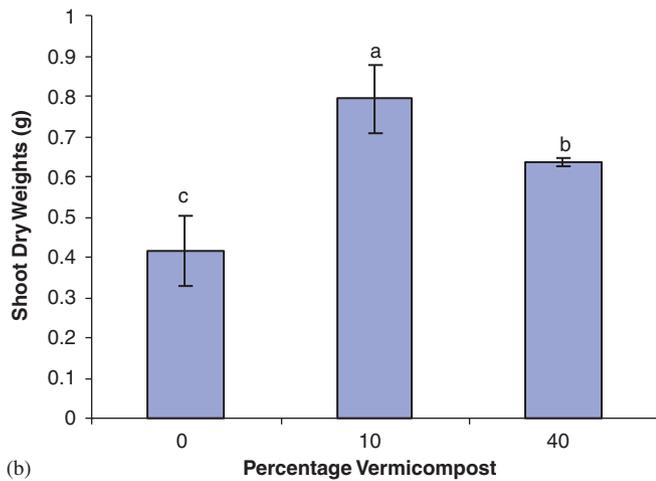
grown with inorganic N (Bentz et al., 1995), and also increase insect population growth rates (Culliney and Pimentel, 1986, Jansson and Smiowitz, 1986). Additionally, a slower rate of nutrient release from organic materials (Patriquin et al., 1995), an enhanced nutritional composition and decreased N levels in plants grown with organic fertilizers (Steffen et al., 1995) could all contribute to the resistance of these plants to arthropod pest attacks. Phelan et al. (1996) suggested that the acceptability of corn, to the corn borer *Ostrinia nubilalis* (Hubner), could possibly be mediated by the plant's mineral balance and also by a biological buffering characteristic of organically managed soils (Phelan et al., 1995, 2004). Vermicomposts are known



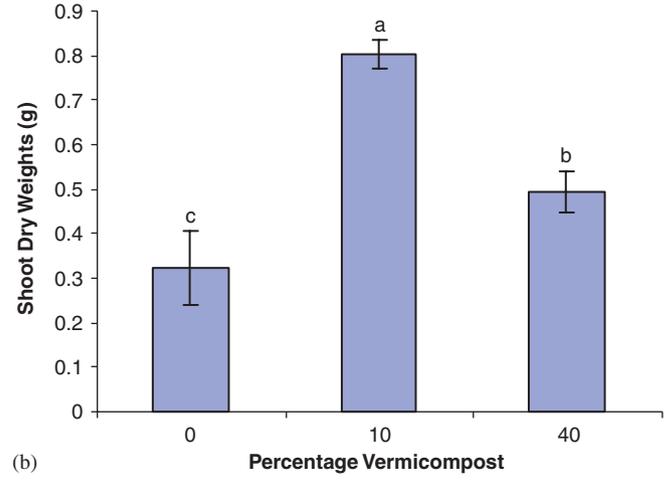
(a) Percentage Vermicompost



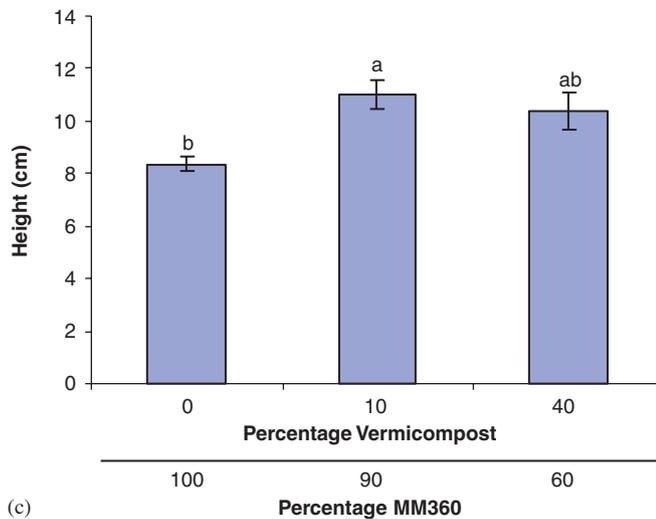
(a) Percentage Vermicompost



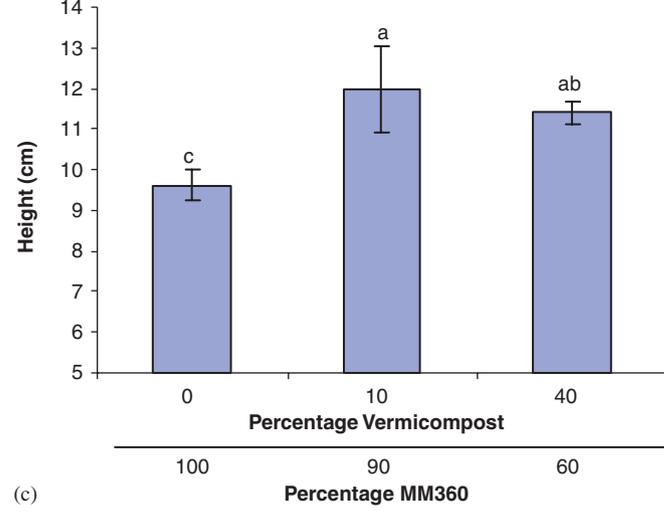
(b) Percentage Vermicompost



(b) Percentage Vermicompost



(c) Percentage MM360



(c) Percentage MM360

Fig. 9. Effects of aphid infestations on cabbage (a) leaf areas (b) shoot dry weights (c) heights after 17 days of growth, when supplied with all needed nutrients. Means followed by same letter(s) are not significantly different at  $P \leq 0.05$ .

Fig. 10. Effects of aphid infestations on cabbage (a) leaf areas (b) shoot dry weights (c) heights after 17 days of growth, with no additional nutrients supplied. Means followed by same letter(s) are not significantly different at  $P \leq 0.05$ .

to provide a slow, balanced nutritional release pattern to plants, in particular release of plant available N, soluble K, exchangeable Ca, Mg and P (Edwards and Fletcher, 1988; Edwards, 1998). Moreover, vermicomposts have a much greater microbial diversity and activity than conventional

thermophilic composts, because organic wastes fragmented by earthworms have a greater surface area and therefore support much more microbial activity. Additionally microbial activity tends to be largely suppressed by the high temperatures reached during thermophilic

composting. In our experiments, the combination of slow release of nutrients and high microbial activity from vermicomposts seems to have indirectly enhanced the plants capacity to suppress pest insect attacks. We also suggest that a component of the mechanisms inhibiting attack by arthropod pests by vermicomposts and similar organic materials, on the foliage and fruits of crop plants, may be due to feeding responses to different forms of N in the plant foliage.

It is well known that phenolic substances are distasteful to secondary decomposers in soil systems and inhibit the breakdown of dead plant materials (Edwards and Heath, 1963; Heath and Edwards, 1964). Simmonds (1998) reviewed the modification of insect feeding behavior by phenolics and non-protein amino acids and general inhibition of insect pest feeding. Asami et al. (2003) reported that total amounts of phenolic substances were much higher in strawberries and corn grown organically than in those grown with inorganic fertilizers. It has also been shown that sprays of phenols and phenolic acids extracted from ginkgo plants were as effective in controlling attacks by cotton aphids, vegetable aphids, caterpillars and thrips, as several pesticides that are approved to control these pests. Stevenson et al. (1993) reported inhibition of development of *Spodoptera litura* by a phenolic compound from the wild ground nut. Haukioja et al. (2002) reported that phenolics in plant tissues changed rates of consumption of tissues by a geometrid caterpillar *Epirrita autumnata*.

We hypothesize that the decreased insect pest numbers and damage on plants grown with vermicomposts, in both our greenhouse and field experiments (Yardim et al., 2006), could be attributed at least partially to changes in the form of N, a controlled slower release rates of mineral nutrients and particularly by the production of phenolics through the use of vermicomposts. Further research is needed to support this hypothesis and to further identify mechanisms by which vermicompost suppress arthropod pest feeding and reproduction.

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